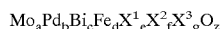


Ca, Sr, Ba, Zr, Hf, Ni, P, Pb, Sb, Si, Sn, Ti, U, Re, Te, La and Pd; a, b, c, d, e and f represent the gram atom ratios of the elements such that $0 < a \leq 1$; $0 \leq b < 1$; $a + b = 1$; $10^{-5} < c \leq 0.02$; $0 < d \leq 2$; $0 < e \leq 1$; and $0 < f \leq 2$. This catalyst is disclosed in U.S. Pat. No. 6,333,444 B1 as being useful for the oxidation of ethane or ethylene to acetic acid. This patent is incorporated herein by reference.

[0085] The catalyst may be an oxidation catalyst having a calcined composition represented by the formula $\text{Mo}_a\text{V}_b\text{Nb}_c\text{Pd}_d$, wherein: 1 is 1 to 5; b is 0 to 0.5; c is 0.01 to 0.5; and d is 0 to 0.2. This catalyst is disclosed in U.S. Pat. No. 6,383,977 B1 for converting ethane to acetic acid. This patent is incorporated herein by reference.

[0086] U.S. Pat. No. 6,441,227 B1, which is incorporated herein by reference, discloses two oxidation catalysts which can be used separately or in combination with each other in the inventive process. The first catalyst is a mixed metal oxide represented by formula



[0087] wherein: X^1 is at least one or more of Co, Ni, V, Pt or Rh; X^2 is at least one or more of Al, Ga, Ge, Mn, Nb, Zn, Ag, P, Si or W; X^3 is at least one or more of K, Mg, Rb, Ca, Sr, Ba, Na or In; O is oxygen, and a is 1; $0 < b \leq 0.3$; $0 < c \leq 0.9$; $0 < d \leq 0.9$; $0 < e \leq 0.9$; $0 < f \leq 0.9$; $0 < g \leq 0.3$; and z is a number which satisfies the valences of the other elements in the formula. This catalyst is described as being useful for converting olefins to alpha-beta unsaturated aldehydes. The second catalyst is a metal oxide represented by the formula



[0088] wherein X is W or Mn or both; Y is at least one or more of Pd, Sb, Ca, P, Ga, Ge, Si, Mg, Nb or K; O is oxygen, and a, is 1; b, is 0.01 to 0.9; $0 < c_1 \leq 0.2$; $0 < d_1 \leq 0.5$; $0 < e_1 \leq 0.5$; and z_1 is a number which satisfies the valences of the other elements in the formula. This catalyst is described as being suitable for converting an alpha-beta unsaturated aldehyde to an alpha-beta unsaturated carboxylic acid.

[0089] The catalyst may comprise an ammoxidation catalyst represented by the formula



[0090] wherein A is one or more of the elements selected from Co, Mn, Cr, P, Sb, Te, Na, Ce or W, a is a number from 0 to 5; b is a number from 0 to 0.4; c is a number from 0 to 0.4, provided that the sum of b and c is from 0.1 to 0.4; d, e, f, and g are numbers from about 0.2 to 10, and x is a number determined by the valence requirements of the other elements. This catalyst is disclosed in U.S. Pat. No. 5,093,299 as being useful for the conversion of an olefin (e.g., propylene or isobutylene) to the corresponding unsaturated nitrile (e.g., acrylonitrile or methacrylonitrile) by reacting the olefin, ammonia and oxygen in the presence of the foregoing catalyst. This patent is incorporated herein by reference.

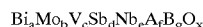
[0091] The catalyst may comprise an ammoxidation catalyst represented by the formula



[0092] where a is 0.5 to 2; M is one or more of Sn, Ti, Fe or Ga; m is 0.05 to 3; N is one or more of: W, Bi, Mo, Li, Mg, P, Zn, Mn, Te, Ge, Nb, Zr, Cr, Al, Cu, Ce or B; n is 0.0 to 0.5; and x is a number determined by the degree of

oxidation of each of the other elements. This catalyst is disclosed in U.S. Pat. No. 5,258,543 as being useful for the ammoxidation of C_3 to C_5 monoolefins to alpha, beta-monounsaturated acyclic nitrites (e.g., acrylonitrile) having 3 to 5 carbon atoms.

[0093] U.S. Pat. No. 6,486,091 B1, which is incorporated herein by reference, discloses an ammoxidation catalyst represented by the formula



[0094] wherein: A is one or more elements selected from groups VB (e.g., V, Nb, Ta), VIB (e.g., Cr, Mo, W), VIIB (e.g., Mn, Tc, Re) or VIII (e.g., Fe, Co, Ni) of the periodic table; B is at least one alkali promoter selected from groups IA (e.g., Li, Na, K) or IIA (e.g., Mg, Ca) of the periodic table; a is 0.01 to 12; b is 0.01 to 12; c is 0.01 to 2; d is 0.01 to 10; e is 0.01 to 1; f is 0 to 2; g is 0 to 1; and x is the number of oxygen atoms required to satisfy the valency requirements of the elements present. This catalyst is described as being useful for converting olefins to unsaturated nitriles.

[0095] The sorption medium may comprise metal ions that are complexed (e.g., chelated) by ligands. The metal ions may complex with O_2 , or other fluid components to be separated. The metal ions that may be used include Fe(II), Co(II), Cu(I), V(II), Mn(II), Mn(III), Cr(II), Ag(I), Rh(I), Rh(II), Rh(III), U(IV), V(IV), Ru(II), Ru(IV), Ti(III), Cr(IV), Bi(III), Ni(II), W(V), W(IV), Mo(II), Mo(III), Mo(IV), Mo(V), Mo(VI), or a combination of two or more thereof. The Roman numerals in the foregoing indicate oxidation states or valence numbers for the ions.

[0096] The ligands that may be used to complex the metal ions include dipyridyl; 2,6-[1-(2-imidazol-4-ylethylimino)ethyl pyridine]; cyclen; cyclam; a Schiff base ligand; acetyl acetate or an oligomer or polymer thereof; a carboxylate; bipyridyl or an oligomer or polymer thereof; a porphyrin or an oligomer or polymer thereof; a corin or an oligomer or polymer thereof; a polyamide; a protein; 8-hydroxy quinine or an oligomer or polymer thereof; ethyl cysteinate or an oligomer or polymer thereof; an N-alkyl alkanohydroxamic acid; dimethylglyoxime; sym-diethylethylenediamine; or a combination of two or more thereof. The ligands may include fluoride-carbon bonds. The ligands may be fluorinated (e.g., perfluorinated).

[0097] In one embodiment, the metal-ion ligand complex may be an axial ligand. These ligands may be suitable for oxygen purification because they tend to provide suitable bonds with oxygen to allow adduct formation, but not oxidation of the metal. Examples include imidazole, histidine amino acid, pyridine, piperidine, 4-methyl aminopyridine, 4-dimethyl aminopyridine, a nitrate, a thiocyanate, a halide, or a combination of two or more thereof.

[0098] The sorption medium that may be used may be hemoglobin; hemoerythrin; hemocyanin; myoglobin; Co(II) (acacen); Co(II) (dry cave) (N-methyl imidazole); Fe(II) (H_2TpvPP)B; Fe(II)(capped porphyrin)B; Fe(phen) $_2^{2+}$; bis(ethyl cysteinato) oxovanadium (IV); Cu(I) (bimp); bis(dimethylglyoximate)cobalt(II); bis(histidine)cobalt(II); dinitrato-bis(sym-diethylethylenediamine)cobalt(II); dichloro-bis(sym-diethylethylenediamine)cobalt(II); [m-tetra(a,a,a,a-o-pivalamidophenyl)porphyrin]cobalt(II); [N,N-bis(salicylidene)dipropylentriamine]cobalt(II); [2,3,10,11,13,19-hexamethyl-3,10,14,18,21,25-